Set 8.0: Atomic Structure

Skill 8.01: Be able to calculate the percent composition of an element in a compound
Skill 8.02: Summarize Dalton's laws
Skill 8.03: Summarize the experiments which led current model of the atom
Skill 8.04: Define and identify the atomic number for an element
Skill 8.05: Define and identify the mass number for an element calculate the number of neutrons in an atom
Skill 8.06: Be able to identify isotopes
Skill 8.07: Identify the number of electrons, protons, and neutrons in a cation or anion

Skill 8.01: Be able to calculate the percent composition of an element in a compound

Skill 8.01 Concepts

John Dalton proposed the basic laws that today serve as the foundation for atomic theory. The first of these laws is the law of conservation of matter:

When a chemical reaction takes place, matter is neither created nor destroyed.

The second law is known as the law of constant composition:

Multiple samples of any pure chemical compound always contain the same percent by mass of each element making up the compound

For example, a 160.0 g sample of copper(I) sulfide (Cu_2S) contains 128.0 g of copper (Cu) and 32.0 g of sulfur (S). The percent by mass of these elements is therefore:

$$\% \text{ copper } = \frac{\text{mass of copper}}{\text{mass compound}} = \frac{128.0g}{160.0g} = 80.00\%$$

$$\% \text{ sulfur } = \frac{\text{mass of sulfur}}{\text{mass compound}} = \frac{32.0g}{160.0g} = 20.0\%$$

These same percentages are found in any sample of pure copper(I)sulfide, no matter where it comes from or what the size of the sample is.

Skill 8.01 Example 1

50. g of pure water (H_2O) is decomposed into its components, you obtain a 5.6 g sample of hydrogen gas and a 44.4 g sample of oxygen gas.
(a) What is the percent mass of each of these elements in water?
(b) What is the percentage of hydrogen and oxygen in a 65 g sample of pure water (H_2O)?

Skill 8.01 Example 2

A 58.5 g sample of a compound of carbon and oxygen is 47.1% by mass oxygen
(a) What is the percent by mass of carbon in this compound?
(b) What is the mass of oxygen in the compound?
(c) What is the mass of carbon in the compound?

Skill 8.02: Summarize Dalton's laws

Skill 8.02 Concepts

Based on the law of conversation of matter and the law of constant composition, Dalton formulated his atomic theory, which can be summarized in five short statements:

1. All matter is made up of atoms
2. Atoms can neither be created nor destroyed
3. Atoms of a particular element are alike in size, mass, and properties
4. Atoms of different elements are different
5. A reaction involves the union or the separation of individual atoms.

Skill 8.03: Summarize the experiments which led current model of the atom

Skill 8.03 Concepts

Once the existence of atoms was accepted, the next obvious question was, "What do atoms look like?". A series of experiments showed that atoms are NOT fundamental particles of matter but are themselves composed of even smaller particles.

In 1897, Thomson discovered the first particle to be identified, the **electron.**

−   All atoms contain electrons
−   All electrons are identical
−   All electrons are assigned a -1 charge

In 1907, Thomson and Goldstein discovered the **proton.**

−   The proton is MUCH heavier than the electron (about the size of one hydrogen atom).
−   All protons are assigned a +1 charge.

In 1932, Chadwick discovered the **neutron.**

－ All neutrons are about the size of a proton.
－ Neutrons are assigned a charge of zero.

Once it was established that atoms were composed of electrons, protons, and neutrons, the next question was, "How were these subatomic particles put together?"

Rutherford's alpha-particle experiment confirmed the presence of a **nucleus.**
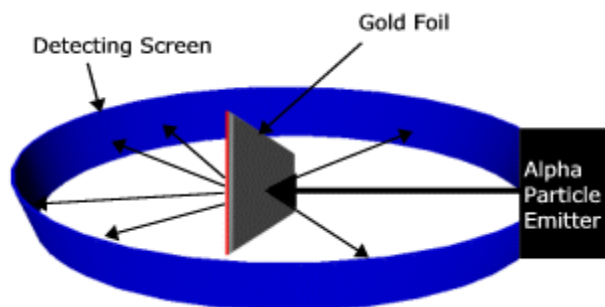
Rutherford observed that most of the alpha particles WERE NOT deflected by the gold foil, but rather passed through; only 1 in about 10,000 were deflected. Rutherford concluded that something very small, dense, and positive was contained within each atom of the gold foil. He called this the nucleus. From Rutherford's experiments and others that followed, scientists were able to conclude the following.

－ The neutrons and protons reside in the nucleus
－ The nucleus makes up most of the mass of the atom
－ The nucleus has a positive charge
－ The electrons move about outside the nucleus. The cloud in which they move accounts for most of the volume of the atom.
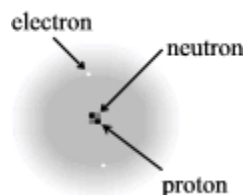
[Skill 8.03 Exercise 1](#)

Skill 8.04: Define and identify the atomic number for an element

Skill 8.04 Concepts

The **atomic number** is defined as the number of protons in an atom.

－ No two atoms can have the same atomic number, in other words, the atomic number identifies the atom.
－ If the atom is neutral, that is there is no charge indicated (e.g., H^+), the atomic number is also equal to the number of electrons in the atom.   In other words the number of protons is equal to the number of electrons.
－ The periodic table is arranged according to increasing atomic number

Skill 8.04 Example 1

For each atom below, identify the element, the number of protons, and the number of electrons (note that the atomic number is always the bottom number when this notation is used):
(a) $^{12}_{6}C$
(b) $^{1}_{1}H$
(c) $^{25}_{12}X$
(d) $^{40}_{19}X$

Skill 8.04 Exercise 1

Skill 8.05: Define and identify the mass number for an element calculate the number of neutrons in an atom

Skill 8.05 Concepts

The mass number is defined as the number of protons and neutrons in an atom. The number of neutrons can be determined by subtracting the atomic number from the mass number.

Mass number – atomic number = number of neutrons

Skill 8.05 Example 1

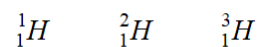| |
|---|
| For each atom below, identify the element, along with the number of number of protons, neutrons, and electrons. |
| (a) $^{131}_{54}X$ |
| (b) ^{208}Bi |
| (c) $^{238}_{92}X$ |
| (d) $^{235}_{92}X$ |

Skill 8.05 Exercise 1

Skill 8.06: Be able to identify isotopes

Skill 8.06 Concepts

Isotopes are different versions of the same element that contain different numbers of neutrons in their nuclei.

For example,

$^{1}_{1}H$ $^{2}_{1}H$ $^{3}_{1}H$

are all isotopes. Although they are all hydrogen atoms because they have one proton in their nucleus, they have a different number of neutrons in their nucleus and hence different mass numbers.

Most naturally occurring elements have more than one isotope. The masses given on the periodic table are reported as an average of these. For example, the natural abundances of carbon-12 and carobon-13 are 98.9% and 1.10% respectively. The atomic average atomic mass can be calculated as follows:

Avg atomic mass of carbon = (0.9890)(12.000000 amu) + (0.0110)(13.00335 amu) = 12.01 amu

Notice on the periodic table that the mass numbers are NOT whole numbers. This is because the mass numbers represent the average mass of all naturally occurring isotopes.

Skill 8.06 Example 1

Identify what each set of atoms has in common.
(a) $^{206}_{83}X$, $^{207}_{83}X$, $^{208}_{83}X$
(b) $^{20}_{10}X$, $^{40}_{30}X$, $^{15}_{5}X$
(c) Which set, (a) or (b), represents a set of isotopes?

Skill 8.06 Exercise 1

Skill 8.07: Identify the number of electrons, protons, and neutrons in a cation or anion

Skill 8.07 Concepts

More often than not the number of electrons in an atom is not equal to the number of protons. When this situation occurs a charge on the atom is present. The charge on an atom is equal to the number of protons minus the number of electrons. Consider the example below:
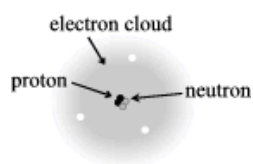
In the example there are 2 protons so the total positive charge is +2; there are also 3 electrons for a total negative charge of -3. The charge on the atom is therefore +2 – 3 = -1.

An atom with a negative charge is defined as an **anion**.
An atom with a positive charge is defined as a **cation**.

To determine the number of electrons, protons, and neutrons in an ion, consider the following example:

$^{108}_{47}X^+$

In this example the number of protons is the atomic number 47, the number of neutrons is the mass number minus the atomic number 108-47=61. The charge on the atom is equal to the protons minus the electrons,

or,

Protons – electrons = charge

Rearranging, the number of electrons is equal to,

Electrons = Protons – charge = 47 – (+1) = 46

Skill 8.07 Example 1

Identify the atom. Then determine the number of protons, electrons, and neutrons in the following ions.
(a) $^{65}_{30}X^{2+}$
(b) $^{88}_{38}X^{2+}$
(c) $^{35}_{17}X^{-}$
(d) $^{14}_{7}X^{3-}$

Skill 8.07 Exercise 1